Dec. 13, 1955 E. O. LAWRENCE ET AL 2,726,805

ION PUMP

Filed Jan. 29, 1953 3 Sheets-Sheet 1

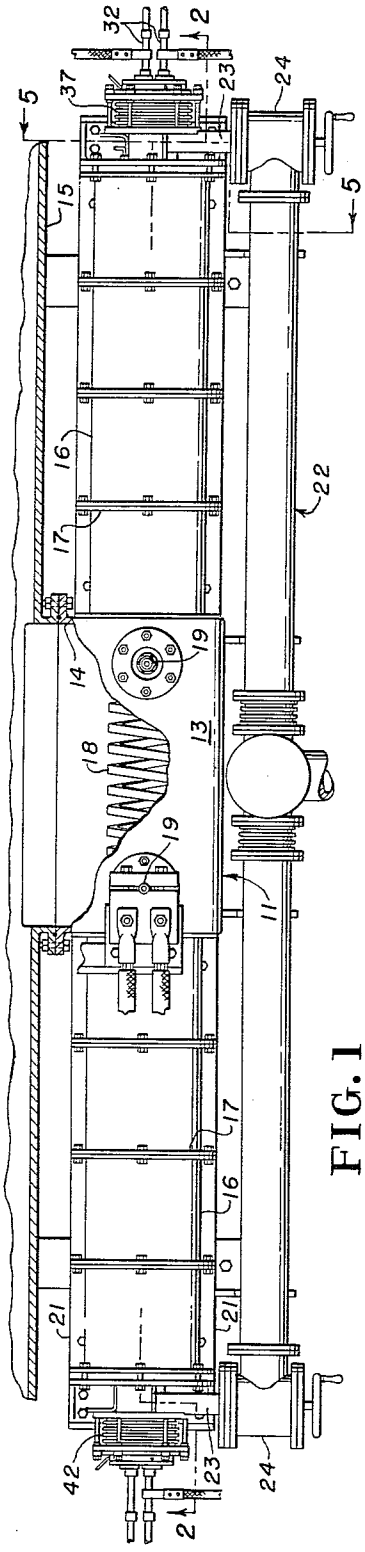


FIG. 1

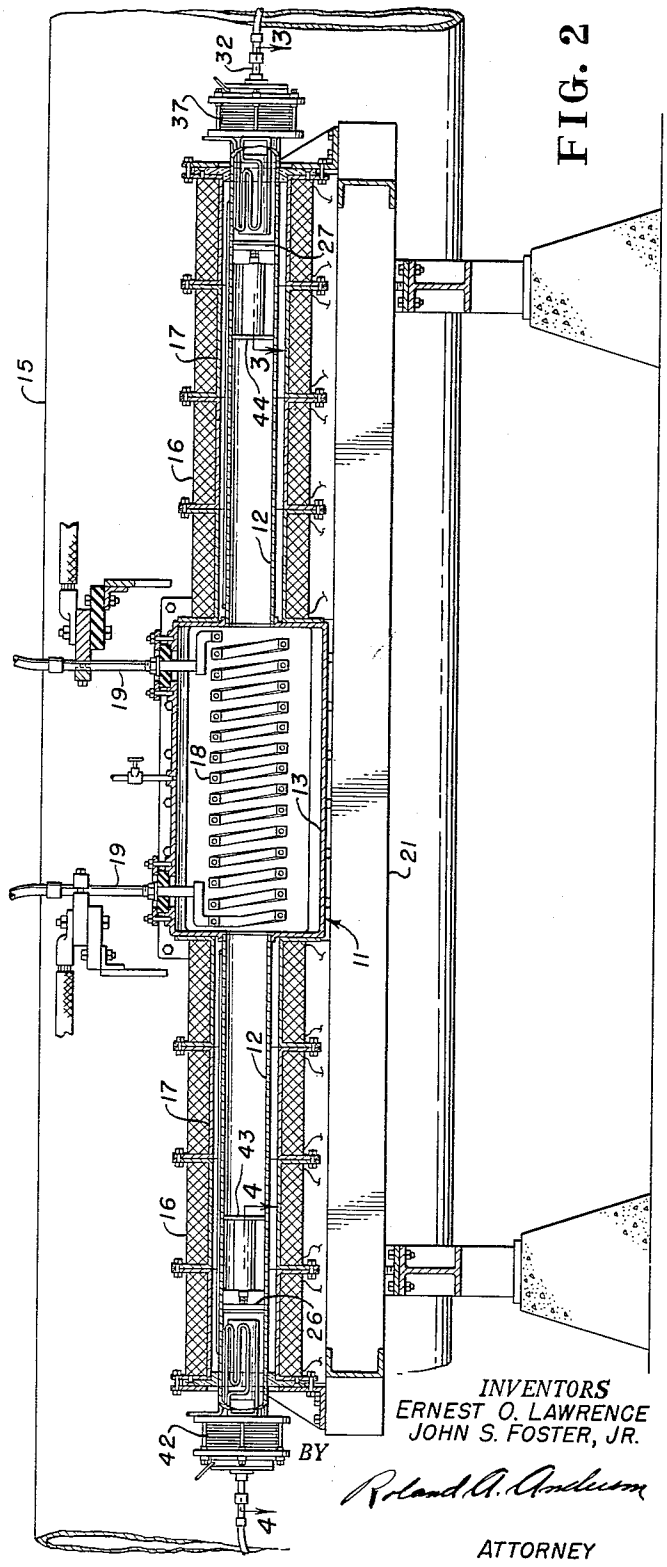


FIG. 2

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FIG. 3

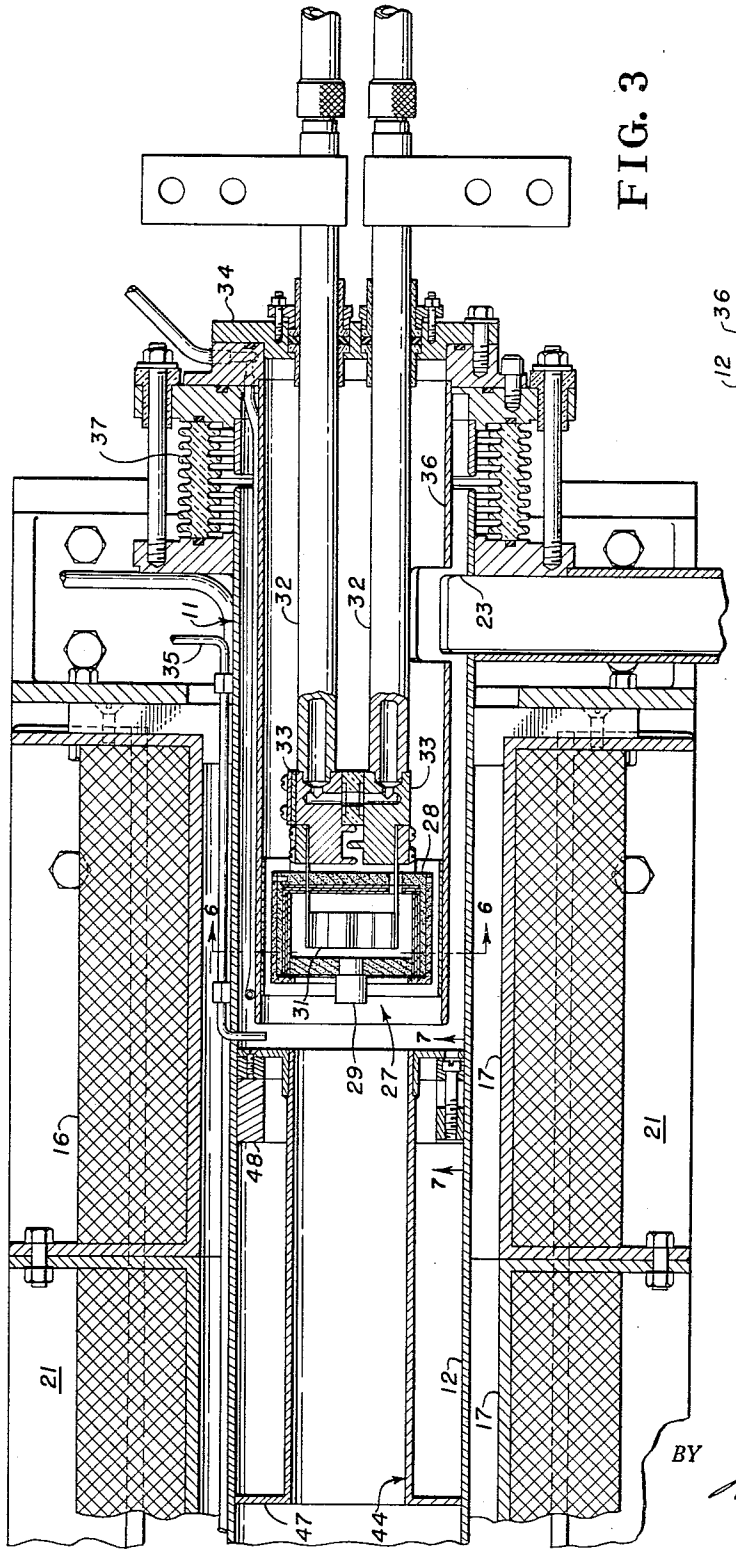


FIG. 6

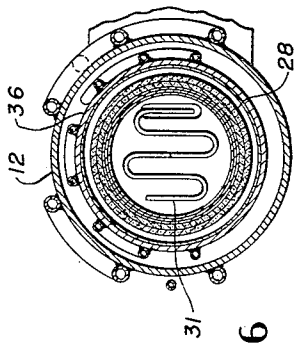
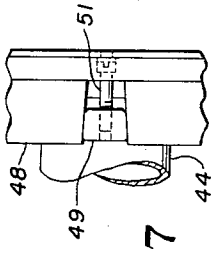


FIG. 7



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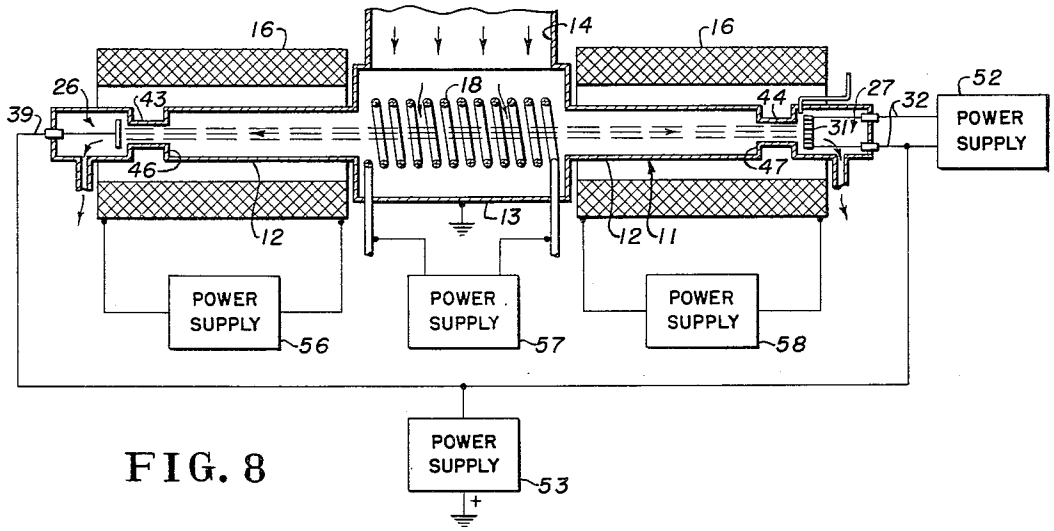


FIG. 8

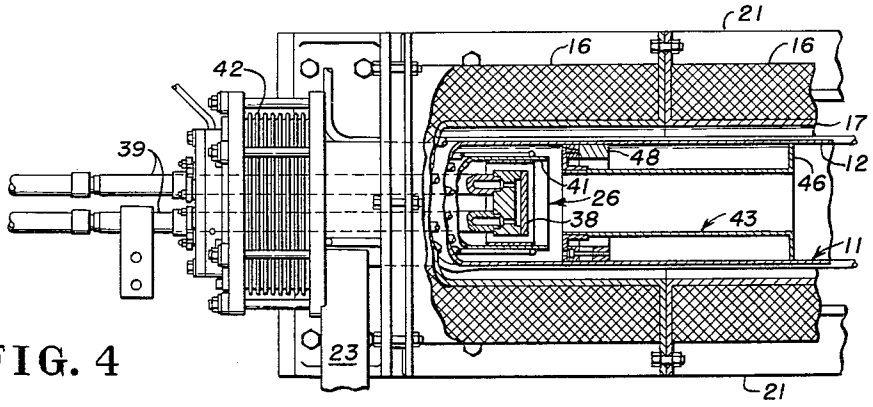


FIG. 4

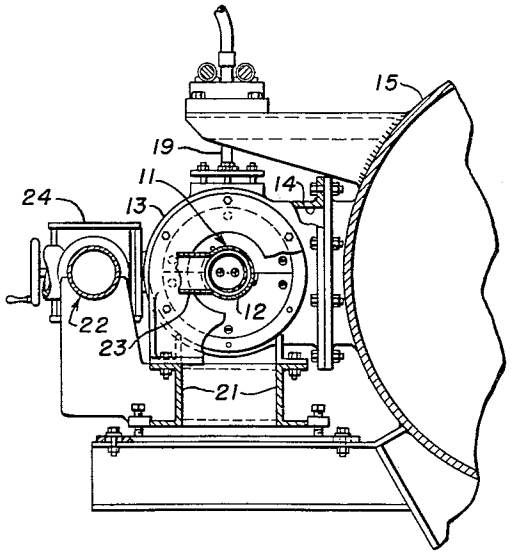


FIG. 5

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2,726,805

ION PUMP

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Application January 29, 1953, Serial No. 333,928

13 Claims. (Cl. 230—69)

The present invention relates to an improvement in vacuum pumping and in particular to method and means for electromagnetically pumping large volumes of gas at very low pressures without the use of a pumping fluid.

Conventional vacuum pumps are either mechanical or employ a pumping fluid to entrain gas for removal, and each of these types of pumps has certain well-known limitations. The present invention contemplates the provision of wholly electromagnetic pumping means having no moving parts and requiring no pumping fluid, to thereby overcome the limitations of prior known vacuum pumping means.

It was early recognized that an electron discharge in a closed envelope tended to reduce the pressure therein and numerous attempts have been made to take advantage of this phenomenon. Upon this basis was developed an ion gauge, Penning, Patent No. 2,197,079, and various other devices, and this pressure reduction idea was employed by W. v. Meyer, as reported in Z. Physic, 84,531 (1931), for vacuum cleanup in very high vacuum work with small containers. Following these early disclosures there have been developed innumerable devices designed to pump gas and operating by an electron discharge; however, to date all of the developments have been limited to very small volume gas transfer. It would appear from the art that the phenomenon of ionization when employed for pumping is a very low order effect and that it could not be employed to provide large pumping speeds. While such is the clear purport of the prior art, the present invention shows this not to be the case when the phenomenon is properly applied and controlled, and the present invention provides electromagnetic pumping means having pumping speeds comparable to a plurality of conventional vacuum pumps in combination. Not only is the present invention capable of providing very high pumping speeds, but also it is much more economical than conventional vacuum pumps in many circumstances and is, in fact, suited for pumping in certain circumstances where conventional vacuum pumps cannot be employed.

Accordingly, it is an object of the present invention to provide an improved electromagnetic vacuum pump.

It is another object of the present invention to provide an improved method and means of pumping gas by ionizing the gas and moving same as ions to a remote point where the gas is neutralized and retained.

It is still another object of the present invention to provide an improved ion pump having a high pumping speed and capable of attaining a very high vacuum.

It is yet another object of the present invention to provide an improved ion pump having means for ionizing gas and transferring same in ionized form together with means for limiting return gas flow.

It is a further object of the present invention to provide an improved vacuum pump having a magnetically collimated arc discharge for ionizing and removing gas from a vessel to be evacuated and means limiting gas flow in the pump to a single direction.

Numerous other advantages and possible objects of the invention will become apparent to those skilled in the art from the following description of construction and operation of a single preferred embodiment of the invention taken together with the attached drawings wherein:

Figure 1 is a plan view of the pump attached to a vessel to be evacuated and partially broken away to show the attachment;

Figure 2 is an elevational view of the pump in longitudinal center section taken at 2—2 of Figure 1;

Figures 3 and 4 are sectional views of the pump ends taken at 3—3 and 4—4, respectively, of Figure 2;

Figure 5 is an end section of the pump taken at 5—5 of Figure 1;

Figure 6 is a transverse sectional view taken at 6—6 of Figure 3 and showing cathode details;

Figure 7 is a sectional view taken at 7—7 of Figure 3 and showing mounting details of the constriction tube; and

Figure 8 is a schematic representation of the pump including associated electrical circuits.

The invention in general as shown in Figure 8 comprises means for establishing a magnetically collimated oscillating electron discharge between negatively charged electrodes and means for admitting gas to the center of the discharge whereby same is ionized to produce an arc plasma having a voltage gradient between the center and ends thereof. The ionized gas thus travels in the arc plasma to the ends thereof where it is neutralized at the electrodes, and limiter or constriction tubes disposed about the arc adjacent each end electrode force gas diffusing back toward the air inlet to pass through the arc where it is reionized and re-delivered to the electrodes. The high electron current in the plasma is a very good ionizing agent so that large volumes of gas are ionized thereby, and in addition the arc plasma provides a one-way path for ionized particles away from the arc center so that gas is removed from the arc center and delivered to the ends thereof to produce a pumping action. This pumping action when properly controlled is capable of a pumping speed of many thousands of liters per second and will operate to produce a vacuum of the order of 10^{-7} millimeters of mercury.

Considering now the structure of a preferred embodiment of the invention as illustrated in the drawings, there is provided a generally cylindrical vacuum envelope 11 which is formed of metal and which may include a pair of end sections 12 and a communicating center section 13, with the center section 13 thereof having a greater diameter than the end sections 12 and being joined to the end sections in vacuum-tight connection. An inlet aperture 14 is provided in the center of vacuum envelope 11 for communication with a vessel 15 to be evacuated and to this end center section 13 has one side thereof open and flanged whereby same may be connected in vacuum-tight relation to vessel 15.

There is provided means for establishing a magnetic field longitudinally through envelope 11, and this may include a plurality of magnet windings 16 disposed end-to-end about the end sections 12 of envelope 11 and wound upon flanged cylinders 17 which may be rigidly joined together as by bolts through the flanges to form the equivalent of a single, long multiple-turn solenoid about each of the end envelope sections 12. The magnetic field through the center of envelope 11 and between end sections 12 thereof may be best provided by a large open helix 18 formed of heavy hollow conductor and disposed longitudinally within envelope center section 13. Helix 18 may be mounted and supported by rigid hollow electrical conductors 19 attached to the ends thereof and extending through the top of center section 13 in rigid and insulated relation thereto to suspend helix 18 therein. These conductors 19 are electrically joined to terminals exterior to the pump proper and these terminals, which are adapted to have suitable energizing means connected thereto through a plurality of electrical leads

adapted to carry a heavy current, as shown, are mounted in insulated relation upon the vessel to be evacuated. A suitable source of cooling water may also be attached to conductors 19 for providing flow of cooling medium therethrough to prevent overheating thereof from the large currents necessarily passed therethrough to establish a strong magnetic field with the relatively few turns thereof.

While the requisite rigidity and support of the pump may, of course, be provided in a variety of ways, the illustrated embodiment provides structural strength in center section 13 and the attached cylinders 17, about which magnet windings 16 are disposed, and the end sections 12 of envelope 11 are mounted within the magnet cylinders 17 in electrical contact with center section 13. The above combination is mounted as at the ends thereof upon a pair of rigid beams 21 which extend parallel to and beneath the envelope-magnet combination and which may be either individually supported or may be rigidly mounted, as by welded brackets, upon vessel 15, as shown. Under certain conditions of operation, as noted below, it is necessary to provide a backing pump operating in conjunction with the present invention and there may thus be provided a vacuum manifold 22 having an outlet pipe connected thereto and being adapted for connection to the inlet of a roughing pump. Vacuum manifold 22 communicates with envelope 11 through apertures 23 in one or both ends thereof and valves 24 may be placed in these connections.

With regard to the internal structure of the pump, there is provided a pair of cathodes 26 and 27 disposed one at each end of envelope 11 and interior thereto. At least one of these cathodes is electron emissive to provide electrons for the arc discharge within envelope 11, and in the illustrated embodiment the cathode at the right in Figure 2 is electron emissive, the other cathode 26 serving only as an electron reflector. Cathode 27 may have any of a variety of configurations; however, as it is subject to heavy ion bombardment, it is desirable for it to be quite sturdily constructed. One or more cold cathodes, such as aluminum, may be employed or a heated cathode may be used, the one illustrated in Figure 3 comprising an indirectly heated cathode. Cathode 27 comprises a closed box 28 having heat shields on all interior walls thereof except the front wall, which is preferably formed of a very hard and rugged material to withstand ion bombardment. The front wall may be formed of an electron emissive material such as tungsten or may, as shown, be formed of a refractory material such as carbon with a central plug of tungsten or the like; in either instance the exterior of the front wall comprises in whole or in part an electron emissive surface 29. Electron emission is produced by indirect heating of emissive surface 29 and there is provided for this purpose a filament 31 disposed within box 28. Filament 31 is energized through a pair of rigid hollow electrical conductors 32 which are placed in electrical contact with opposite ends of filament 31 by connectors 33. The ends of filament 31 extend through the back wall of box 28 with at least one end of filament 31 being out of electrical contact with box 28 and the filament ends are held in clamped relation to connectors 33 which, in turn, are apertured to each receive one of the electrical conductors 32. An insulator is provided between connectors 33 and a passageway is formed between the apertures in connectors 33 through the insulator to provide communication between hollow conductors 32 and thereby provide a path for cooling water from a source thereof attached to conductors 32 exterior to envelope 11. The above-noted cathode structure 27 may be suspended upon conductors 32, as shown, and conductors 32 may, in turn, be mounted in insulating relation through the end plate 34 of a cylinder 36 which extends within envelope 11 about cathode structure 27 and is apertured to communicate with aperture 23 in envelope 11. End plate 34 is mounted, as by bolts, to the end of the magnet winding structure and attached envelope 11 and is insulated therefrom as by a cylindrical insulator 37 which also serves as a part of the vacuum vessel by closing the gap between the end of envelope 11 and an inwardly projecting extension of end plate 34. The entire cathode structure including cylinder 36 and conductors 32 are insulated from the envelope 11, and the magnet winding cylinders 17 and conductors 32 are adapted for connection to a source of cooling water, not shown, and to suitable power supplies, as noted below. Inasmuch as a large amount of heat is produced by ion bombardment within envelope 11 there may be provided cooling tubes about same and about cathode cylinder 36; which tubes are also connected to a source of cooling water, not shown. A gas inlet tube 35 extends through envelope 11 in the vicinity of cathode 27 and may be connected externally of envelope 11 to a source of gas (not shown).

At the opposite end of envelope 11 there is disposed the other cathode 26 and while it may be constructed the same as cathode 27 it need only function as an electron reflector and thus need not be electron emissive, cathode 27 providing sufficient electrons to establish and maintain the desired discharge. As illustrated in Figure 4, reflector cathode 26 includes a block 38 of metal which may have a removable face plate and which has a pair of rigid hollow electrical conductors 39 secured to the back thereof. Conductors 39 extend exterior to envelope 11 and they may engage the end structure of the magnet winding cylinders 17 in much the same manner as do conductors 32 of cathode 27. A cylinder 41 may be disposed about cathode 26 interior to envelope 11 and there may be provided cooling tubes thereabout, as shown. Cathode 26, conductors 39, and cylinder 41 are mounted in insulated relation to envelope 11 by a cylindrical insulator 42 similar in construction and mounting to insulator 37 of cathode structure 27. Cathode conductors 39 are adapted for connection to a source of cooling water exterior to envelope 11 which circulates water through conductors 39 and a communicating passage in block 38, and conductors 39 are also adapted for connection to suitable power supplies, as noted below.

Interior to envelope 11 there are provided a pair of like constriction tubes 43 and 44 disposed adjacent cathodes 26 and 27 respectively. Constriction tubes 43 and 44 are disposed concentric with envelope 11 and each has a diameter substantially equal to that of the arc discharge that is supported within envelope 11. Tubes 43 and 44 have outwardly extending flanges 46 and 47, respectively, at adjacent ends thereof and these flanges engage the inner surface of envelope 11, preferably in slidable relation. Constriction tubes 43 and 44 may be secured in position by any suitable means; however, it is desirable to mount tubes 43 and 44 in removable relation to envelope 11 and to this end there may be provided split rings 48 disposed about an end of each tube. As shown in Figure 7, ring 48 has a tapered split therein and a wedge plug 49 is disposed therein with a bolt 51 extending through a flange about the end of tube 44 and threadably engaging wedge plug 49. Tightening bolt 51 urges wedge plug 49 further into the split in ring 48 so as to expand same against envelope 11 and hold attached tube 44 in position. The mounting means for both constriction tubes 43 and 44 may be the same.

Considering now the electrical circuit of the invention and referring to Figure 8, there is provided a filament current power supply 52 connected between filament leads 32 for providing heating current to filament 31. Anode-cathode voltage is provided by a direct current power supply 53 which may have the negative terminal thereof connected to cathodes 26 and 27, as at leads 39 and 32 thereof respectively, and the positive terminal grounded. With the above connection of power supply 53, the envelope 11 is grounded as shown, and while this circuitry is advantageous in that the envelope insulation problem is minimized, it will be appreciated that it is only neces-

sary to provide a voltage difference between envelope **11** and cathodes **26** and **27** with neither requiring grounding. Magnet current may be provided by a single power supply or may, as shown, be provided by power supplies **56**, **57**, and **58** with power supplies **56** and **58** each connected across one of the magnet end sections including serially connected windings **16** and power supply **57** connected across helix **18**. Inasmuch as helix **18** has much fewer turns than magnet windings **17**, it is necessary to provide a much higher magnet current through helix **18** in order that a substantially uniform magnetic field will be produced throughout the length of envelope **11**. In addition to the above-noted elements and connections there may be further provided suitable control and interlock means to conveniently operate the system either manually or automatically.

Considering now the operation of the illustrated embodiment of the invention and referring generally to Figure 8, the pump is first connected to a vessel **15** to be evacuated with communication being provided therebetween at aperture **14** in the center section **13** of pump envelope **11**. Energization of magnet windings **16** by power supplies **56** and **58** and energization of helix **18** by high current power supply **57** produces a strong magnetic field having lines of force passing axially through envelope **11**. Energization of cathode **27** is accomplished by connecting power supply **52** across filament **31** to cause a heavy current flow therethrough. The temperature of filament **31** is raised and heat is radiated therefrom to raise the temperature of the electron emissive surface **29** of cathode **27** so that electrons are emitted therefrom. Connection of power supply **53** between envelope **11** and cathodes **26** and **27** places envelope **11** at a relatively positive potential with respect to cathodes **26** and **27** so that envelope **11** effectively comprises an anode and electrons are attracted from cathode **27**. The axial magnetic field through anode envelope **11** collimates the electron discharge and constrains the electrons to pass through envelope **11**, actually in tight helixes about magnetic lines of force, until they approach cathode **26**, at which point they are repelled by the relatively negative charge thereon. The electron discharge established within envelope **11** is thus oscillatory in that electrons oscillate through anode envelope **11** between cathodes **26** and **27** under the constraining influence of the magnetic field and the repelling and attracting forces of the cathodes and anode envelope, respectively.

Admission of air or gas into envelope **11**, as through aperture **14**, results in ionization thereof by the electron discharge and because of the elongated electron path the probability of ionization is very high. The electron discharge thus becomes a high intensity arc discharge with the arc plasma extending as a cylinder through envelope **11** into close proximity with cathodes **26** and **27**. As is the characteristic of arcs, the arc discharge assumes substantially the potential of the most positive electrode producing same so that it has approximately the potential of anode envelope **11**. Almost the entire potential drop occurs in a very short distance between the arc ends and cathodes **26** and **27** and for a typical installation this may be about 500 volts, i. e., cathodes **26** and **27** may be maintained some 500 volts below ground potential.

With regard to the arc discharge established, it is first noted that the electrons thereof have an elongated path and pass back and forth therethrough losing energy by excitation and ionization until they eventually fall out of the arc and are collected by the anode walls. The positive ions of the arc, being of much greater weight than the electrons, have a much lower velocity and a short mean free path so that they develop a positive space charge in the arc column. This charge is greatest at the center of the arc so that the positively charged ions move away from the arc center toward the ends thereof, being laterally confined within the arc column by the magnetic field. Ionization of incoming gas is accomplished by electrons and ions within the arc and substantially all gas molecules entering anode envelope **11** through aperture **14** are ionized very close to their entrance point. The use of helix **18** provides means for establishing substantially the same magnetic field through center section **13** as is provided in end sections **12** by magnet windings **16** and at the same time presents an open structure through which incoming gas may readily enter the arc.

The gas pressure in anode envelope **11**, and thus communicating vessel **15** is thus reduced by the above-noted process wherein gas molecules are ionized and transported away from the arc center. As the ions reach the ends of the arc they are accelerated across the short gap between the arc ends and the cathode to impinge upon the cathode. The ions striking the cathode may either combine with the cathode material and stay there or may pick up an electron to become a neutral particle or gas molecule. The ion bombardment of the cathode surface causes some sputtering of the electron emissive surface thereof and this is deposited upon adjacent surfaces to produce a gettering action whereby some of the ions neutralized at the cathode are trapped on these surfaces. Of the remaining neutral particles some at least will diffuse away from the cathode back along envelope **11** toward the center thereof and under normal conditions would tend to raise the pressure at the envelope center. This gas flow is prevented in the present invention by constriction tubes **43** and **44** which have almost the same diameter as the arc column. Gas flowing away from cathodes **26** and **27** toward the air inlet **14** must pass through constriction tubes **43** or **44** and are thus reionized by the arc discharge therein. No other opening is available for gas to flow back toward air inlet **14** and thus no gas can reach air inlet **14** from cathodes **26** and **27** without passing through the arc wherein it is reionized and redelivered to the adjacent cathode.

With regard to the backing pump, it will be appreciated that with a base vacuum being maintained in vacuum manifold **22** some of the ions neutralized at the cathodes will pass into the vacuum manifold and be pumped away. Experimentation has shown that unless an inert gas is being pumped by the improved ion pump there need not be employed a backing pump and exhaust valves **24** may be closed, the chemical process at the cathodes reaching equilibrium with the pumping speed so that substantially all incoming gas eventually combines with the cathode material.

Considering the relative magnitude of the abovementioned phenomena within the pump, it is noted that the pumping speed of the pump is dependent upon a variety of factors and may be defined as:

$$S=\frac{\Delta L}{\Delta P}$$

wherein:

S is pumping speed
ΔL is change in gas volume inlet
ΔP is pressure change produced by ΔL

The pumping speed is limited by the surface area of the arc discharge exposed to the air inlet so that it is desirable as in the illustrated embodiment of the invention to expose a large arc surface to the air inlet. For a given arc discharge area A the maximum pumping speed S_{max} is:

$$S_{max}=\frac{VaA}{4}K$$

wherein:

Va=Arithmetic average molecular velocity
K=A constant depending upon the overall efficient of the arc as a sink for molecules.

The value of K has been found to be about 0.5–0.3 in a typical pump designed in accordance with the present in-

vention and the pumping speed may be about 75 liters/sec./square inch. A total pumping speed of some 6000 liters/sec. may thus be readily achieved. The base able as in the illustrated embodiment of the invention to pressure of the pump is the summation of a number of effects, as for example, outgassing of the internal pump elements; however, after a short period of operation this is reduced to such a low order as to be negligible. A certain portion of the base pressure is generated by ions falling out of the arc and striking the anode walls wherein they are neutralized; however, the strong axial magnetic field minimizes this phenomena by restricting radial ion travel. Most of the ions which leave the arc column migrate along magnetic lines of force until they strike constriction tube ends 46 and 47. The ions striking constriction tube end surfaces 46 and 47 are neutralized so that these surfaces in effect become sources of gas molecules which tend to diffuse back toward the pump inlet. Inasmuch as the neutral gas molecules are not constrained by the magnetic field they have a random motion and the pump envelope is made long enough that in the distance between constriction tube ends 46 and 47 and pump inlet 14 there is a high probability that the gas molecules will fall into the arc and become reionized. It is also possible that neutral particles may be formed within the arc as a result of electron-ion attachment; however, this is normally considered a rare event in gaseous discharges, but does play a significant part in the present device.

Minimization of back pressure is obtained by the above-noted elongation of the pump to limit back diffusion of gas molecules formed at the pump ends and by constricting the anode diameter adjacent the cathodes to preclude back flow of gas molecules from the cathodes. Also, variation of the hot cathode temperature is effective to control or limit radiofrequency plasma oscillations which may be set up and which tend to increase ion drain across the magnetic field. Further, the arc voltage employed determines in part the relative magnitudes of recombination within the arc, the ionization thereof, and the excitation. The magnetic field intensity along the anode envelope is also of importance and generally optimum results are obtained with a uniform field strength.

In summary it may be noted that the present improved ion pump provides a high intensity magnetically collimated arc for ionization and transportation of gas to be pumped. A relatively large arc surface is exposed to the inlet aperture at the arc center for maximum pumping speed and the anode envelope diameter is constricted immediately adjacent the end cathodes which in combination with the cylindrical anode and axial magnetic field establish a refluxing arc discharge for efficient ionization. The relatively low ion mobility compared with the electron mobility in the arc produces an electric field gradient along the arc which urges ions away from the arc center toward the cathodes. Ions reaching the cathodes are there neutralized and neutral gas molecules diffusing back toward the pump inlet must pass through the anode constriction so that they are reionized by the arc which substantially fills the constriction.

A pressure differential is maintained between the pump inlet 14 and the cathodes, and in a typical pump the pressure in center section 13 may be about 10^{-7} to 10^{-6} mm. of mercury while the pressure at the cathodes is about 5×10^{-4} mm. of mercury. A certain minimum amount of gas molecules is required to maintain the arc which otherwise extinguishes and in the present invention this gas may be provided through gas leak tube 35. An external gas source (not shown) is connected to tube 35 which then feeds gas into one end of the arc adjacent cathode 27. A particular advantage of the present invention is here apparent for the gas pressure need only exceed the minimum at the arc end to maintain the arc and none of the gas admitted through tube 35 passes along envelope 11 to raise the pressure at the pump inlet. The arc is maintained by holding a sufficient pressure at one cathode and the pump inlet pressure falls much lower than the cathode pressure. The anode constrictions prevent reverse gas flow of gas let in at the cathode and thus the arc is in effect maintained to effectuate pumping in a pressure below that at which the arc extinguishes.

It will be appreciated that numerous modifications and variations of the invention may be made within the spirit and scope thereof as for example the vacuum manifold may be attached to either or both ends of the anode envelope. It is thus not intended that the invention shall be limited by the present disclosure of a single preferred embodiment but rather attention is invited to the following claims for a precise definition of the invention.

What is claimed is:

1. An ion pump comprising an elongated envelope, inlet means communicating with the interior of said envelope adjacent the longitudinal center thereof and adapted for connection to a vessel to be evacuated, means establishing an electron discharge longitudinally of said envelope for ionizing gas entering same through said inlet means and thereby producing an arc discharge within said envelope, means removing ions from the ends of said arc discharge and neutralizing same, and means directing return gas flow from the ends of said arc discharge through the discharge wherein same is reionized and redelivered to the arc discharge ends, thereby providing a pumping action from the center to the ends of said envelope.

2. An ion pump comprising an elongated envelope, a pair of separated electrodes disposed within said envelope with at least one of same being electron emissive, means establishing a magnetic field through said envelope directed between said electrodes, power supply means connected between said envelope and electrodes for maintaining said electrodes electrically negative with respect to said envelope whereby an oscillating electron discharge is maintained within said envelope between said electrodes, inlet means communicating with the interior of said envelope midway between said electrodes and adapted for connection to a vessel to be evacuated whereby gas therefrom is ionized by said electron discharge to produce an arc plasma within said envelope, ionization at the middle of said arc plasma producing a potential gradient therein whereby ions in the plasma travel to said electrodes and are there neutralized, and constriction means about said arc plasma adjacent said electrodes for directing gas diffusing from said electrodes toward said inlet means through a substantial length of said arc plasma whereby said gas is reionized and returned to the electrodes so that the arc plasma removes gas from the envelope center.

3. An improved ion pump comprising an envelope, means establishing an oscillating electron discharge within said envelope, inlet means communicating with the interior of said envelope adjacent the middle of said discharge and adapted for connection to a vessel to be evacuated whereby gas enters said envelope and is ionized by said discharge, said discharge thereby becoming an arc discharge including a plasma in which ionized gas molecules migrate to the ends thereof, means magnetically collimating said arc discharge, and limiting means disposed at the ends of said arc plasma for substantially eliminating return gas flow from the ends of the plasma by restricting gas flow to the arc plasma volume.

4. An improved ion pump as defined in claim 3 further defined by said limiting means including means neutralizing ions reaching the end of said arc and constrictions in said envelope about said arc adjacent each end thereof whereby neutralized ions diffusing from the arc ends toward the arc center are constrained to travel through the arc whereby same are reionized and directed away from the arc center.

5. An ion pump comprising an envelope having an

aperture at the middle thereof for communication with a vessel to be evacuated, means including a pair of electrodes disposed one at each end of said envelope for establishing an oscillating electron discharge therein whereby gas entering said envelope through the aperture therein is ionized to produce an arc discharge between said electrodes, and restriction means between each of said electrodes and the center of said envelope, said means each having a passage therethrough of substantially the same diameter as the arc discharge whereby neutral particles can travel from said electrodes toward the center of said envelope only through said arc discharge.

6. An improved ion pump comprising an envelope having a pair of gas outlets disposed one at each of the ends thereof and a gas inlet at the center thereof, means establishing an ionizing arc discharge through said envelope between said gas outlets and past said gas inlet with the center of said discharge being electrically positive with respect to the ends thereof whereby gas entering said inlet is ionized and travels to the ends of said arc whereat same is neutralized, and a pair of envelope constrictions disposed with one adjacent each end of said envelope about said arc and each having a passage therethrough of substantially the same diameter as said arc discharge whereby gas flow from said outlets toward said inlet is constrained to the arc discharge area wherein such gas is reionized and thereby prevented from reaching said gas inlet.

7. An improved vacuum pump comprising a cylindrical envelope having a gas inlet aperture at the center thereof, means including a pair of electrically negative electrodes disposed one at each of the opposite ends of said envelope for establishing an ionizing electrical discharge in the form of an arc through said envelope past said inlet aperture and ionizing gas entering therethrough, said arc being electrically negative at the ends with respect to the center thereof whereby ionized gas travels to the ends of said arc and is there neutralized at said electrodes, and a pair of members disposed within said envelope one adjacent each of said electrodes about said arc and each having elongated passages therethrough of substantially the diameter of said arc whereby gas at said electrodes can only reach the center of said envelope through said passages and is thus reionized therein by said arc and is returned to said electrodes.

8. An improved ion pump comprising an elongated cylindrical anode having an inlet aperture at the center thereof, a pair of cathodes disposed one at each of the opposite ends of said anode within same for establishing an ionizing discharge through said anode, means establishing a magnetic field having lines of force longitudinally through said anode for collimating the discharge therethrough, said discharge ionizing incoming gas to become an arc discharge having a voltage gradient urging ions toward the arc ends whereby ions travel to the arc ends and strike said cathodes, and a pair of constrictions within said anode cylinder adjacent said cathodes toward the center of said anode cylinder therefrom for limiting gas flow from the cathodes toward the inlet aperture to the arc discharge wherein the gas is reionized and redelivered to the cathodes.

9. An improved ion pump comprising an elongated anode cylinder, means establishing a magnetic field having lines of force through said cylinder, a pair of cathodes disposed one at each end of said cylinder, a power supply maintaining said cathodes at a negative potential with respect to said anode for producing an oscillating electron discharge through said anode cylinder collimated by said magnetic field, an inlet aperture in said anode cylinder spaced equidistant between the cathodes therein and adapted for connection to a vessel to be evacuated whereby gas enters therethrough and is ionized by said electron discharge to produce an arc discharge therefrom, said ionized gas traveling to said cathodes where it is neutralized, and constriction tubes disposed within said anode cylinder on the inlet side of said cathodes and adjacent same, said constriction tubes having a diameter substantially equal to that of the collimated arc discharge whereby back flow of gas from said cathodes toward said inlet is constrained to pass through a substantial arc length wherein the gas is ionized and returned to the cathodes.

10. An improved ion pump comprising a cylindrical envelope having an expanded center section with a large inlet aperture therein adapted for connection to a vessel to be evacuated, a large open helical magnet winding disposed axially of said envelope internally of the center section thereof, a plurality of magnet windings disposed about said envelope exterior thereto, power supply means connected to said internal and external magnet windings for energizing same to produce a strong magnetic field axially through said envelope, means including a pair of cathodes equally spaced on opposite sides of said inlet aperture for establishing an oscillating electron discharge through said envelope whereby gas entering same through said inlet aperture is ionized to produce a magnetically collimated arc discharge through said envelope with the ions thereof producing a space charge establishing a voltage gradient between the center and ends of said arc discharge, ions formed by said arc being delivered to the ends thereof by said voltage gradient and said ions being neutralized at said cathodes, and means directing return gas flow from said cathodes through a substantial portion of said arc whereby said gas is reionized and redelivered to said cathodes.

11. An improved ion pump comprising an envelope, means establishing an elongated magnetically collimated arc discharge through said envelope, a pump inlet connected to said envelope at the center of said arc discharge whereby gas entering through said inlet is ionized by said arc to form potential gradient between the center and ends of said arc thereby urging ions toward the ends of said arc, means disposed adjacent the ends of said arc for neutralizing ions reaching same, and means constricting said envelope to the arc discharge area adjacent the arc ends whereby gas diffusing from said ion neutralizing means toward said pump inlet is directed through said arc and is reionized and redelivered to said neutralizing means.

12. An improved ion pump comprising an elongated cylindrical envelope having a large inlet aperture at the longitudinal center thereof and a smaller outlet aperture at one end thereof, means including an open helical winding at the center of said envelope for establishing a strong magnetic field axially through said envelope, and a pair of electrodes disposed one at each end of said envelope for establishing an electron discharge therethrough collimated by said magnetic field to a diameter much less than that of said envelope, said discharge ionizing gas entering through said inlet aperture to become an arc discharge having a potential gradient urging ions to the ends thereof where same strike said electrodes and are neutralized, said envelope having a constriction reducing the diameter thereof substantially to the diameter of said arc discharge immediately adjacent each of said electrodes struck by ions from said arc for limiting the return path for neutralized gas ions to that of the arc wherein they are reionized and returned to the electrode.

13. An improved ion pump as claimed in claim 12 further defined by gas inlet means adjacent one of said electrodes on the opposite side of said envelope constriction from the envelope inlet aperture for admitting a small amount of gas to the electrode whereby said arc is maintained at very low pressures at the envelope center.

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